NEW DIRECTIONS FOR ADVANCED GUN TUBES

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Introduction

The mission of the U.S. Army Research Office (ARO) is to seed scientific and far-reaching technological discoveries that enhance Army capabilities. As such, during the past 20 years, ARO has addressed a broad spectrum of challenges at the basic research level including aspects of corrosion, refractory materials erosion, novel electroplating, adhesion, analytical methods for determining hydrogen concentrations in materials, corrosion prevention with novel coatings, and composite laminates. This research was driven by concerns about higher-temperature pressure-explosive effects on gun tubes, increased resistance to pitting, general corrosion, and hydrogen embrittlement of Army equipment. Overall objectives are for increased reliability and maintainability in addition to improved performance and new capabilities.

SBIR Program

Gun tube requirements for longer range and more rapid fire have provided severe challenges to current and planned systems. As the 21st century commences, new technology beyond thin coatings is required to help gun tubes survive expected conditions. In response to this challenge, in July 1996, the Army Research Laboratory (ARL) sponsored a Sagamore Workshop on Gun Barrel Wear and Erosion. In September 1996, ARO cosponsored with the University of Michigan a small industrial, academic, and government workshop to assess the future direction of short- and long-term gun tube research and development. Concurrently, explosive bonding of tantalum (Ta) liners was recognized as a short-term solution to foreseeable gun tube needs and was an excellent adjunct for other existing and planned Army efforts. With that information in hand, ARO justified a small business innovative research (SBIR) program.

In response to this initiative, in January 1998, TPL Inc. of Albuquerque, NM, became involved because of its role in demilitarization of propellants, pyrotechnics, and other energetic materials for the U.S. Army and Navy with a Phase I SBIR. Using several byproducts of various demil projects, TPL had already developed a unique explosive where the detonation velocity could be raised or lowered depending on the need.

Development of this explosive formulation provided the incentive for TPL to respond to the ARO-sponsored SBIR Phase I solicitation with a unique approach for explosively bonding thick clads of erosion-resistant metals to the bore of simulated 120mm gun tube sections. The explosive detonation rate was tailored to the velocity requirements of the two metals being clad. A ring of explosive was positioned around the tube of material to be bonded to the gun bore. This led to the first successful explosive bonding of two dissimilar metals inside the bore of a gun tube. These clads were done with sheets of pure Ta and Ta alloys that were rolled into cylinders of the desired length and then welded. Except for the weld seam, these produced a very good surface on the bore of the 8-inch tube.

Phase II SBIR

The success of Phase I was carried over into a Phase II SBIR in late 1998. In this phase, the focal point was switched from 120mm smoothbore gun tubes to 25mm rapid-fire rifled barrels. The goal of this phase was to produce a specimen that could be test fired on a range to validate the erosion resistance of Ta and the strength of the explosive bond.

For the 25mm diameter, it was possible to obtain seamless tubing made of Ta and Ta alloys. The alloy material was manufactured by a powder metallurgy process and, in all probability, contained detrimental interstitial elements known to severely impact mechanical properties. A good clad was never achieved with the alloy. Although harder and significantly less ductile than the pure Ta, the Ta alloy was not subjected to an amount of strain that should have caused it to fail as it did.

To stay on schedule and minimize further costs, the effort was refocused on using pure Ta tubing from a different source. Here, successful clads were immediately achieved. It was also found that Ta could be clad over existing clean rifling with a good bond observed on all surfaces. A good bond was not possible over “shot-out” rifling where poor surface and excessive contaminates prohibited metallurgical bonding.

During the course of these investigations, several interesting capabilities of explosive bonding were developed. In general, one of the desirable attributes of this process is the ability to bond relatively thick layers (when compared with alternative processes such as ion-sputtering) of one metal to another. It was found, however, that one can clad any number of layers over each other so that nearly any desired thickness can be obtained. Furthermore, within the constraints of the sound speeds of the materials, dissimilar metals can be bonded together, creating many possible combinations—each tailored for a specific purpose. The quality of the bond can be determined microscopically via mechanical tests. Microscopically, the interface on a polished specimen illustrates a waveform pattern between the metals. Bend tests and pull tests used to examine the Ta-to-steel bonds indicate exceptional strength at the bond.

Production Method

The production method for using this technology in a barrel program could occur early in the barrel-making process, before anything other than the specified bore to be clad has been machined into the barrel blank. For larger rifled artillery pieces, a steel "substrate" rifling would be introduced to the bore, which would accommodate the extra thickness of the cladding material. After cladding, the barrels could then be turned down to their tapered configuration, chambers bored, etc. Depending on the location of the barrel-making facility, this could either occur on-site or by routing the barrel blanks to facilities at TPL, followed by final preparation at an Army facility equipped to handle such final machining. For prototype testing in this Phase II SBIR, however, existing barrels will be used.

Future Tests

Arrangements are being made to test a truncated Bushmaster barrel at ARL in Aberdeen, MD, with funding help from the Naval Surface Warfare Center. The Team Small Arms group at Aberdeen Test Center will conduct these tests. The test gun will be a smoothbore version that will fire the very energetic M919 ammunition.

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The purpose is to demonstrate the value of thermochemical resistance of thicker clads of Ta for extending barrel service life, not to present a final gun design.

Because pure Ta is a relatively soft material, researchers did not know if it could withstand the stresses associated with rifling in a firing sequence. This eliminates other avenues of possible test failure that could obfuscate the real questions being evaluated. Similarly, the barrel is truncated to reduce the chance of down-bore failures cutting short the testing cycle. The accuracy of this test gun is not an issue in these tests. This technology could be applicable for several smoothbore candidates such as the 120mm gun tubes investigated in Phase I of the SBIR. In the longer term, the technology may also have significant commercial applications in the chemical and refining industry where the cost of refractory metal processing vessels and piping is high.

Conclusion

For gun tube applications, the issue of material hardness can be addressed in later efforts. There are several options to be explored, including the use of specifically designed substrate rifling cited above and employing various Ta alloys, other refractory metals, and hardness-enhancing surface treatments such as nitriding.

While TPL has not yet field-tested these experimental barrels, tests should be complete by the time this article is published. Information garnered in this program will advance the military knowledge base of extending barrel service.

Note: Just before this issue went to press, the *Army AL&T* staff was informed that testing was concluded at Aberdeen Proving Ground, MD, during the final week of March. The results were successful and can be obtained by contacting the authors.

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